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X SWINGING-SHUTTER APPARATUS FOR MEASURING SMALL DOSAGES
OF INSECTICIDAL AEROSOL^{1/}

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Liquefied-gas aerosols containing pyrethrum are extremely toxic to mosquitoes (Sullivan, Goodhue, and Fales 1), flies (McGovran, Fales, and Goodhue 6) and other flying insects. Tests with these aerosols must therefore be conducted in large rooms (Lindquist, Travis, Madden, Schroeder, and Jones 4), or, if small rooms are used, precise measurements of very small quantities must be made. The insects are often held in cages during the large-room tests, which procedure introduces a number of sources of error. If the insects are released in a large chamber, considerable time is required to collect them after a test, especially if they are still active, and in addition a great deal of labor is needed to clean the insecticidal residue from the walls, ceiling, and floor.

A Peet-Grady chamber (6 by 6 by 6 feet) is generally available in insecticide-testing laboratories. Such a chamber is large enough to permit normal activity of the insects and dispersion of an aerosol cloud, and yet small enough for the insects to be readily collected and the chamber cleaned between tests.

Goodhue and Sullivan (3) published a drawing of a laboratory apparatus for testing small amounts of aerosol. With modifications and refinements a dosage of 0.25 gram was obtained with this apparatus, now called a pressure test tube dispenser. An improved model (Goodhue, Bellinger, and Fales 2) and another apparatus (Batt 1) will produce a satisfactorily dispensed minimum dose of about 0.1 gram of aerosol. Even this small amount usually kills all the mosquitoes in a Peet-Grady chamber, making comparative tests against these insects impossible.

In dispensing the entire content of a pressure tube dispenser that holds a measured amount of aerosol delivery is constant at the maximum pressure but varies at the beginning and the end of the discharge period.

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This is of little importance when large amounts of aerosol are released, but when the entire dosage is released in a fraction of a second, the variation in delivery may materially change the average size of the aerosol drops. Unless the pressure reaches a maximum in a fraction of a second and drops off very quickly, a considerable proportion of the aerosol will be discharged at pressures below the normal for practical applications.

This paper describes an apparatus which was developed to dispense accurately measured small dosages of liquefied-gas aerosols into a Peet-Grady or smaller testing chamber.

SWINGING-SHUTTER APPARATUS

The apparatus developed is an application of the principle of a uniformly swinging shutter cutting the spray stream so that uniform deliveries during a fraction of a second can be obtained. The same principle has been applied in another manner in a roach-testing method (McGovran and Fales 5). A cabinet containing the shutter, space for an aerosol dispenser, dispenser shut-off mechanism, and an exhaust fan is mounted on the side of a Peet-Grady chamber (Figs. 1 and 2). A round hole, 1 inch in diameter, connects the cabinet with the chamber and is 8 inches below the ceiling and 9 to 12 inches from one corner. This hole can be opened and closed by the shutter which swings like a pendulum. The stream of aerosol is dispersed against this shutter as it swings back and forth, permitting a given amount of aerosol to pass into the chamber. Variations in dosage can be obtained by changing the number of swings of the shutter, the size of the opening in it, or the rate of discharge from the aerosol dispenser.

Cabinet

The cabinet is 38 inches high, 20 inches wide, and 12 inches deep (outside measurements), and made of wood with a sheet-metal back. It is divided into three sections. The left rear corner of the cabinet may be made shallower than the remainder of the cabinet (Fig. 1) in order to fit over the corner post of some Peet-Grady chambers. The cabinet can be the same depth throughout where chamber construction permits (Fig. 2).

The upper section is 18 1/2 inches high and has two glass doors. A removable rack, with an upright attached (Fig. 1, G, and Fig. 3), securely holds the aerosol dispenser. The rack fits into a wooden stand on the floor of this section and is held in place with door buttons. The dispenser is mounted on the stand with a metal clamp. The discharge tube is secured in a groove in the upright by heavy rubber bands. A 1-inch hole in the metal back of the cabinet fits against a similar hole in the wall of the Peet-Grady chamber. This hole is opposite the tip of the discharge tube on the aerosol dispen-

ser (A). The top of the swinging shutter (B), which operates by means of a ball-bearing mounting (K), extends over the hole. The weight (E), and other apparatus to open and close the dispenser are also in this section.

The middle section of the cabinet is $11\frac{1}{4}$ inches high and has one wooden door. This section holds an exhaust fan (I), and an air filter (H) consisting of a wooden frame and four layers of white flannel. The intake of the exhaust fan is covered with two layers of heavy flannel cloth. The fan discharges outside the cabinet. The ball-bearing mounting (K) of the swinging shutter is in the back of this section.

The lower section of the cabinet is $8\frac{1}{4}$ inches high and open at the front. The lower end of the swinging shutter extends into this section. To the tip of the shutter is attached a lead ball 2 inches in diameter (J), which swings like a pendulum and assists in giving the shutter its uniform motion. A frame on the floor of this section controls the amplitude of the swing. A block can be placed in this frame to hold the shutter in position.

Swinging Shutter

The swinging shutter (Fig. 4) is made of heavy sheet metal 26 inches long and 7 inches wide. A 1-inch hole (A) through which the aerosol is delivered into the Peet-Grady chamber is $1/2$ inch below the top edge of the shutter. A 3-by 3-inch metal plate with a slit in the center (B) fits over this hole to reduce the size of the opening. Along the edges of the slit are $1/4$ -inch flanges extending at right angles from the plate, to prevent droplets of insecticide that splash off the shutter from entering the spray stream and being carried into the test chamber. The plate is attached to the shutter with metal clips. By using plates with slits of different width the rate of discharge into the chamber can be controlled. The axle (C), with ball bearing, supporting the shutter is attached to the metal back of the cabinet. There is $1/16$ -inch clearance between the shutter and the back.

Shut-off Apparatus

This apparatus (Fig. 1, D, E, and F, and Fig. 5) is used to release the aerosol from an aerosol container into the closed cabinet. A rubber pad is pressed against the tip of the delivery tube to prevent the aerosol from being sprayed. This pad is a section of inner tube 1 inch square by $1/8$ inch thick, which is inserted in the grooves of a metal holder. This flat-backed metal holder is mounted tangentially on a horizontal round iron rod, which is bent at a 90° angle at its right end to form an L. Rotating the horizontal section of the rod through 180° presses the rubber against or removes it from the tip of the aerosol delivery tube.

The L-shaped rod (Fig. 1, D) is mounted in the upper section of the cabinet, the long arm extending across the back of the section just in front of the shutter and just below the opening into the chamber. There is a weight (Fig. 1, E) on the short arm of the rod. A piece of window sash cord (Fig. 1, F) is tied to this weight, thence up through the top of the cabinet over a pulley and down the outside where it can be fastened. When the cord is loosened the weight drops, turning the long arm so that the rubber covered metal plate pushes forward against the tip of the aerosol dispenser nozzle. The valve on the dispenser may then be opened but no aerosol escapes. Pulling the cord lifts the weight and turns the metal plate away from the nozzle tip and the aerosol begins discharging. It discharges into the cabinet but not into the chamber until the shutter is swung.

Exhaust Fan for Adjustment of Pressure in the Cabinet

On the left outside wall of the cabinet is mounted a manometer filled with heavy white petroleum oil. One end of the manometer opens inside the cabinet and the other end outside. This is not illustrated in the figures.

To prevent the aerosol from leaking out into the room or into the test chamber, a slight negative pressure must be maintained within the cabinet while the aerosol is being discharged. The exhaust fan (Fig. 1, I) withdraws air from the cabinet. The air passes through the cloth filter (Fig. 1, H) and the cloth over the suction intake of the fan, thence out of the cabinet. Since air enters the middle section of the cabinet only through the opening around the shutter in the back of the cabinet, air charged with aerosol is drawn in from the upper section of the cabinet and air from the room is drawn in from the lower section. A cloth-covered opening (4 by 12 inches) in the top of the cabinet (Fig. 1, C) permits sufficient air to enter so that, when the suction fan is running, it produces a negative pressure of 3 to 5 mm. of white oil, as registered on the manometer. Air moves slowly into the upper and middle sections of the cabinet through all openings and cracks, and thus prevents the escape of insecticide particles. Too low a pressure in the cabinet must be avoided since appreciable quantities of air would be withdrawn from the test chamber.

OPERATION

Dispensing the Aerosol

A test is begun by turning on the fan and closing the door of the middle section. The valve on the aerosol dispenser is opened. The doors to the upper section are closed and the shut-off apparatus is then opened. The shut-off is opened while the shutter is in the position shown in Figure 2. Figure 6 illustrates the position of the operator when dispensing the aerosol. Note the left hand holding the

lead weight on the lower end of the shutter and the right hand on the cord that operates the shut-off. As soon as the aerosol discharge becomes uniform, the shutter is released and permitted to swing over and back, at which point it is grasped again. This is repeated until the required dosage has been delivered. The type of spray and movement of the shutter can be observed through the top door.

Testing Commercial Dispensers

A commercial aerosol dispenser is tested by mounting it in a suitable holder (Fig. 7) so that it will discharge into the Peet-Grady chamber when the shutter swings. The cuff of a rubber glove is attached to the edge of a 5 1/4-inch hole in the right side of the top section of the cabinet, with the hand of the glove extending into the cabinet (Fig. 7). The valve on the dispenser is then opened by a hand inside the glove and the swinging shutter operated in the usual manner. With this glove the various types of nozzles on the commercial containers can be operated without disturbing the necessary tightness of the cabinet. The shut-off apparatus described above cannot be used on commercial dispensers and should be removed from the cabinet before starting a test.

AMOUNT OF SOLUTION DELIVERED

Biological Determination

Since other means of determining the amount of aerosol delivered into the test chamber were not readily available when this apparatus was first made, a biological determination was made with Aedes aegypti (L.) mosquitoes. Although an unflanged opening was used on the swinging shutter, the large droplets of insecticide fell quickly to the floor of the chamber and did not appreciably affect the biological determination. Two aerosol solutions containing Freon-12 (dichlorodifluoromethane) were delivered into the test chamber in amounts that would cause mortalities above and below 50 percent. The first solution contained 4 percent of pyrethrum extract (0.8 percent pyrethrins) plus 6 percent of corn oil, and the second 0.25 percent of pyrethrum extract (0.05 percent pyrethrins) plus 9.75 percent of corn oil. The second solution was too dilute for practical use, but was made up at that strength so that kills below 100 percent could be obtained with accurately measured doses delivered from a pressure test-tube dispenser.

A plate with a 1/16-inch slit was mounted on the swinging shutter. The delivery tube used with the first solution put out 0.92 gram of aerosol solution per second. The same delivery tube was used on this one pound dispenser (Fig. 3) and the pressure test tube dispenser used to deliver the second solution.

At a concentration of 4 percent of pyrethrins the mortalities obtained with adult female mosquitoes were 33 percent after two swings and 58 percent after four swings of the shutter. At a concentration of

0.05 percent of pyrethrins for the pressure test tube dispenser, the mortalities obtained were 44 percent at a dosage of 0.15 gram and 60 percent at 0.25 gram. Each mortality is the average of 20 tests of approximately 100 insects each. From these data free-hand curves were plotted. The weight of the second solution required to kill 50 percent of the insects was determined. The weight was then broken down into the weight per swing. To facilitate subsequent calculations, the weight per swing was adjusted to a basis of 1 gram of aerosol solution delivered per second. On this basis the 1/16-inch opening discharged 3.5 mg. of aerosol solution per swing of the shutter.

The following formula is used to determine dosages in milligrams per 1,000 cubic feet: $3.5 \times \underline{R} \times \underline{N} \times 4.63$, in which \underline{R} is the number of grams of aerosol delivered per second by the dispenser, \underline{N} the number of swings of the shutter, 4.63 the relation of the volume of the test chamber to 1,000 cubic feet, and 3.5 the number of milligrams of aerosol delivered per swing when the dispenser delivers 1 gram of solution per second.

Weighing the Aerosol

To weigh the aerosol, a T-tube which collected the aerosol was devised. Suction through this tube carried the aerosol-bearing air through filter paper, which removed the aerosol. The tube fitted over the 1-inch opening into the Peet-Grady chamber. By weighing the tube before and after discharge of the aerosol into it, the weight of the nonvolatile material could be determined. An aerosol solution containing 20 percent of nonvolatile solution was used. The shutter was swung often enough to give a deposit of approximately 100 mg. of non-volatile material in the T-tube. As the material cooled rapidly at the point of discharge, not more than 14 swings were made at one time. With this number of swings, the maximum used in testing, no marked change in the temperature of the delivery tube was noted. After the period of discharge, 15 seconds or less, the dispenser was shut off and the shutter cleaned before additional swings were made.

A series of flanged plates having openings of various widths were used. After numerous preliminary weighings, six weighings were made to determine the quantity of aerosol delivered through each plate. The delivery rates per 1/16 inch of opening in the flanged plate, if the aerosol was delivered at 1 gram per second, were as follows:

Plate openings (inches)	Total aerosol per 1/16 inch of opening per swing (milligrams)	Total aerosol per plate per swing (milligrams)
1	5.13	82.1
15/16	5.13	76.9
14/16	5.13	71.8
13/16	5.13	66.7
12/16	4.87	58.4
11/16	4.87	53.6
3/16	3.79	11.4

The average deviation from the average dosage for a single plate ranged from 0.08 percent to 1.17 percent for individual dosages. With a sufficiently wide selection of plates, and by utilizing the correct opening and number of swings in the formula, any given dosage can be obtained even though the rate of delivery of a dispenser is high or low. For example, if a dosage of 80 mg. of total aerosol solution is desired and the dispenser delivers 0.75 gram per second, two swings with the 11/16-inch opening would give a dosage of 80.4 mg.

Range of Dosage

The swinging-shutter apparatus and procedure for quantitatively dispensing small dosages of liquefied-gas-generated aerosol can give a wide range of dosages. It is a micro method. 3.5 mg. of aerosol solution was delivered into the test chamber in a single swing, and the apparatus could be readily adjusted to deliver smaller amounts. With the largest opening through the shutter that was available, 82 mg. per swing was delivered. If large amounts are desired, 10 to 20 swings can be used for a single dose. This would give a dosage of 0.8 to 1.6 grams of aerosol solution.

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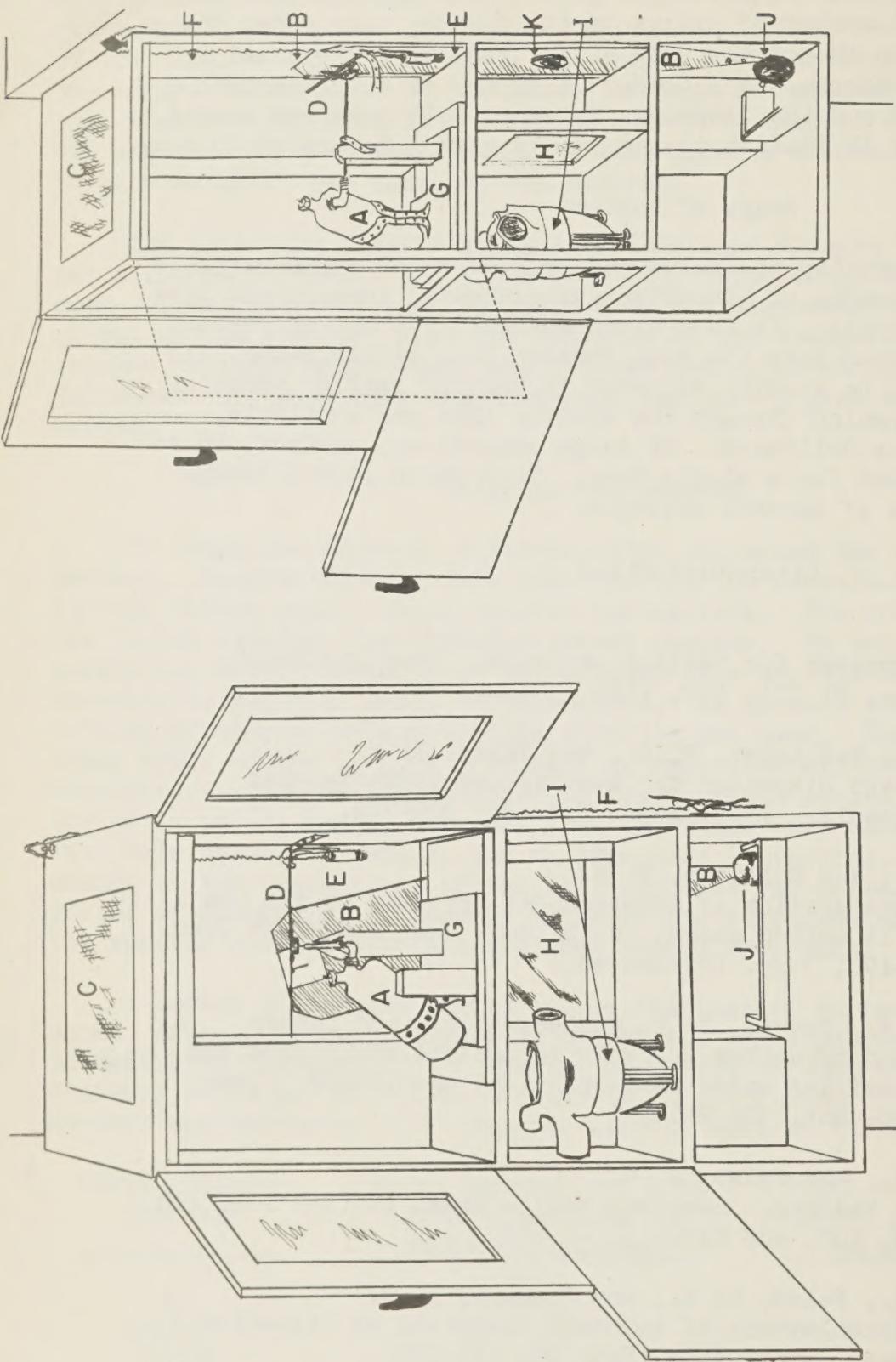


Figure 1.—Front and side views of apparatus for releasing small quantities of aerosol into a Pest-Grady chamber: A, aerosol dispenser; B, swinging shutter showing opening through which aerosol passes into Pest-Grady chamber; C, cloth-covered air intake; D, shut-off rod; E, weight on shut-off rod D. (As weight is raised by the cord the rubber-faced projection on the shut-off rod is rotated away from tip of aerosol dispenser, opening it. As weight falls the rubber is pressed tightly against the tip, closing it.) F, cord for lifting weight E to turn aerosol on and off; G, removable rack for mounting aerosol dispenser; H, cloth filter; I, exhaust fan (vacuum sweeper motor and fan); J, weight on bottom of swinging shutter; K, ball-bearing mounting for shutter.

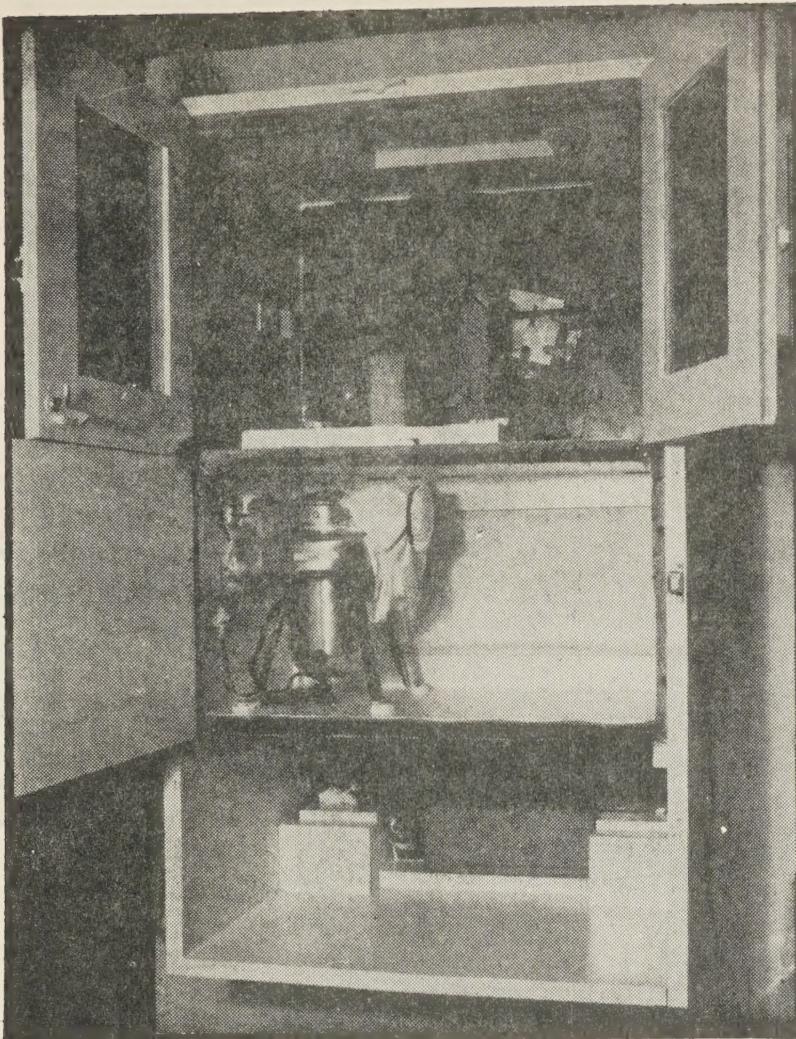


Figure 2.--Front view of cabinet with the doors open.

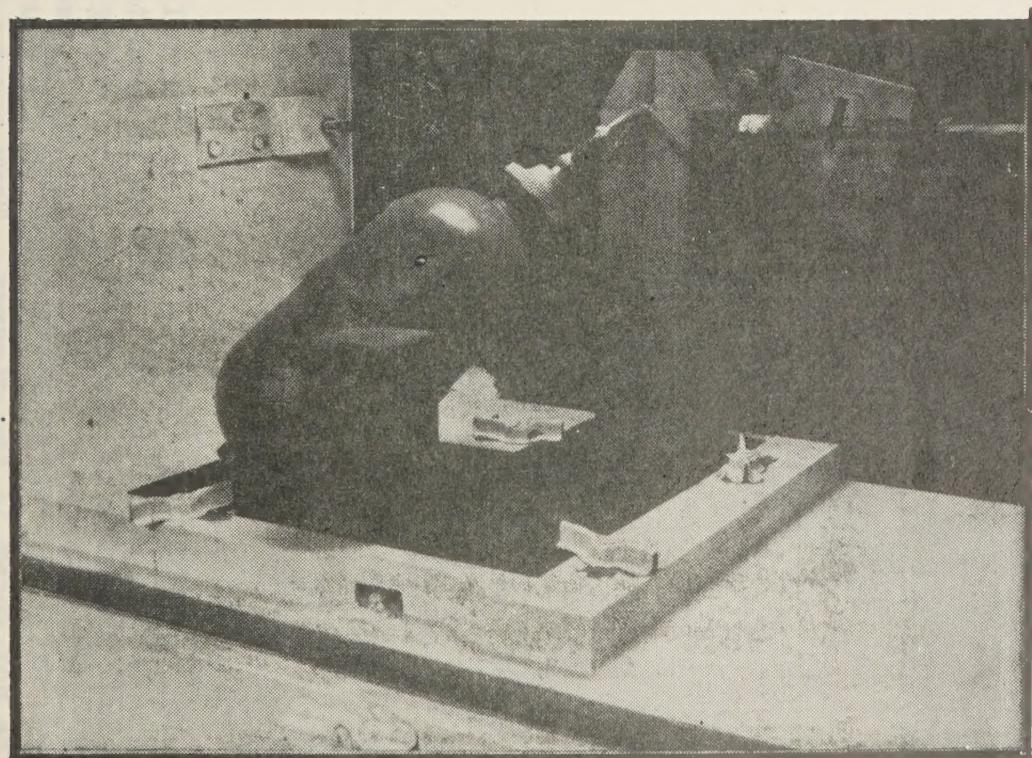


Figure 3.--Dispenser mounted in top section of cabinet.

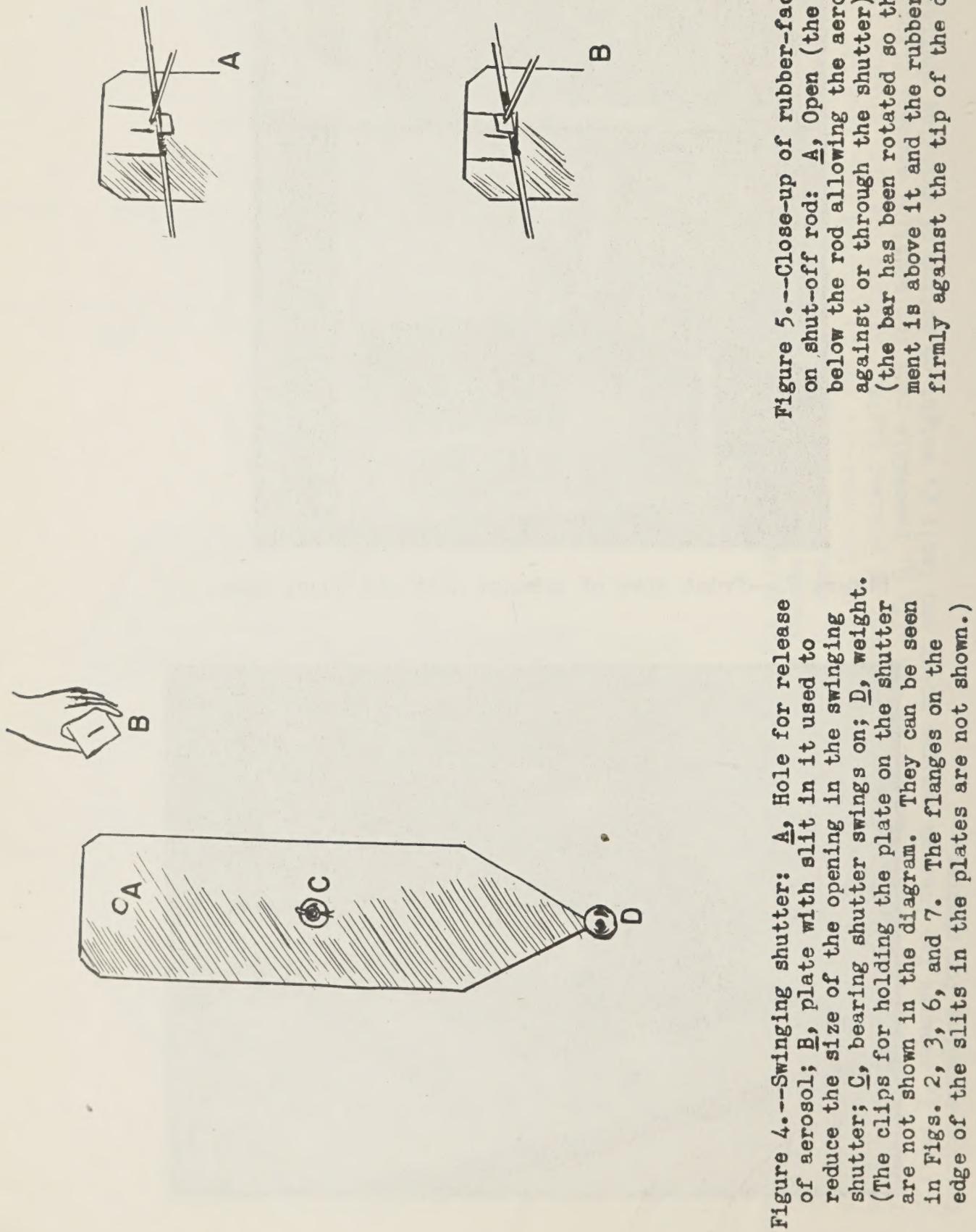


Figure 4.--Swinging shutter: A, Hole for release of aerosol; B, plate with slit in it used to reduce the size of the opening in the swinging shutter; C, bearing shutter swings on; D, weight. (The clips for holding the plate on the shutter are not shown in the diagram. They can be seen in Figs. 2, 3, 6, and 7. The flanges on the edge of the slits in the plates are not shown.)

Figure 5.--Close-up of rubber-faced attachment on shut-off rod: A, Open (the attachment is below the rod allowing the aerosol to spray against or through the shutter). B, Closed (the bar has been rotated so that the attachment is above it and the rubber face is pressed firmly against the tip of the dispenser).

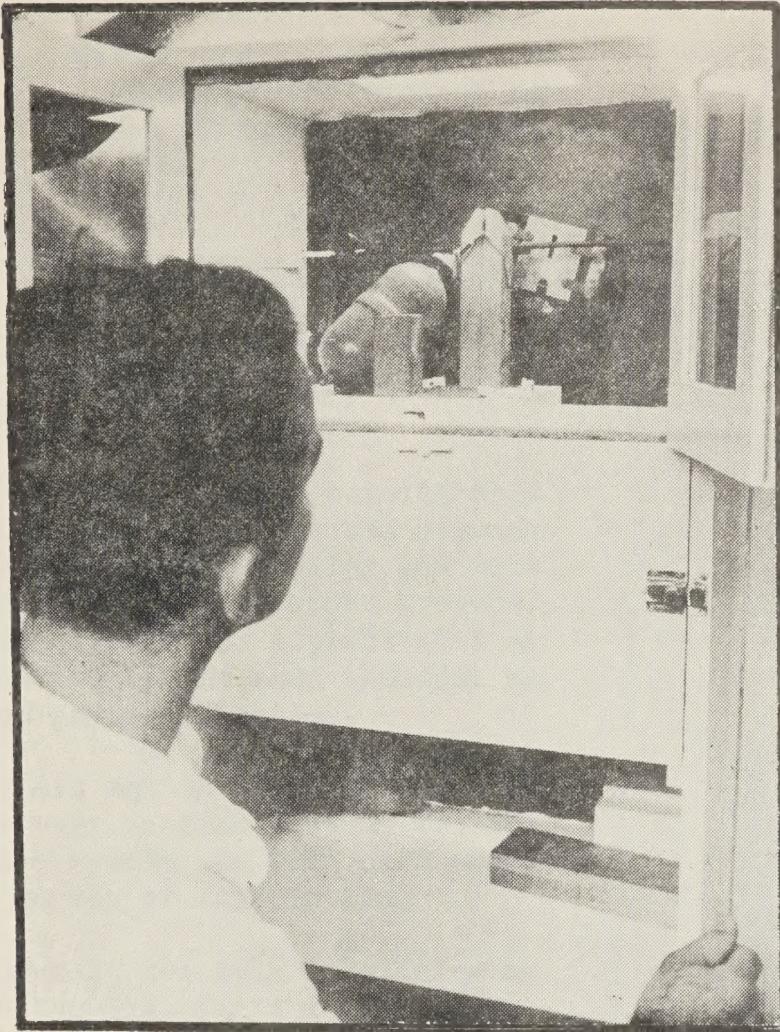


Figure 6.--Position of operator when dispensing aerosol.

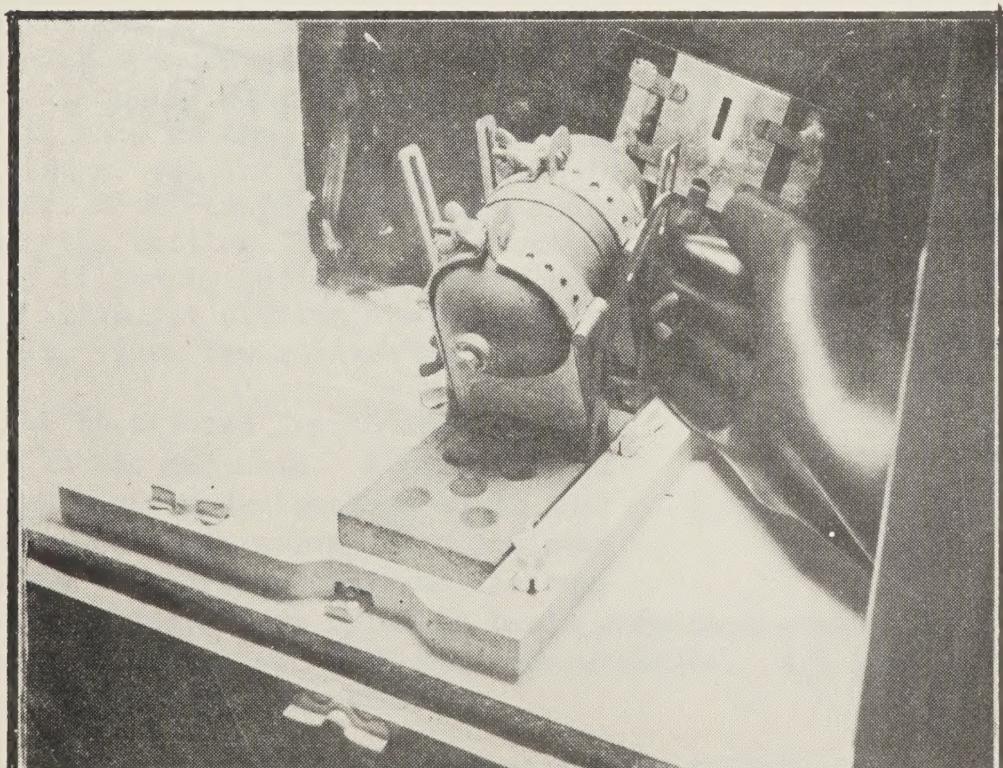


Figure 7.--Rubber glove in side of cabinet for use in manipulating valve on commercial dispenser.

